Structure and Development of the Thyroid Gland in Petromyzon.

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STRUCTURE AND DEVELOPMENT OF THE THYROID GLAND IN PETROMYZON.

Introduction.

The material with which the following work was done was of two, or possibly three, species. The first species was P. planeri, the small lamprey that, in the adult condition, reaches a length of about six inches only. This ~~first lot of~~ material was collected by Dr. R. G. Harrison at Naples. It included stages from the recently fertilized egg to the swimming larva in which the yolk was no longer externally visible and in which the mouth was separated from the pharynx only by a thin partition of cells. This oldest stage was killed fourteen days after fertilization.

The second lot of the material was obtained at Ithaca, N. Y., and probably includes larvae of both P. dorsatus, Wilder (Lake lamprey) and P. branchialis (Brook lamprey), as both species are known to spawn in the same nest and it is impossible to tell to which species the larvae belong. Part of this lot of material was sent me through the courtesy of Prof. S. H. Gage of Cornell; the rest I myself obtained from one of the "nests" in a stream at Ithaca, New York.

I wish to express here my gratitude to my friend Dr. Ross G. Harrison for placing at my disposal the material from which the younger stages of development were made out: to Prof. Simon H. Gage for the really considerable amount of trouble he took in aiding one who was, at the time, wholly unknown to him, to obtain the older stages for this work: and to Prof. Brooks for much valuable aid and many suggestions during the progress of the work.

~~I found~~ I obtained the best results by killing in Corrosive Acetic (95c.c. saturated solution of $HgCl_2$ and 5c.c. glacial acetic acid), hardening in the usual alcohols and staining, in toto, with Borax Carmine and, on the slide, with Lyons Blue. The greatest technical difficulty experienced was in obtaining good preparations of the long, gland cells. Embryos were fixed in a number of ways, but in no single case was a good preparation of the gland cells obtained. Maceration was tried also, but with no success. Some difficulty was experienced also in sectioning the earlier stages, on account of the mass of yolk, but with later stages there was no trouble of this kind.

All the sections were drawn with a camera, though in most cases the details had to be filled in from a series of sections.

Development of the thyroid gland in Petromyzon.

(11th day.) The thyroid begins, in Petromyzon, as a simple pit or groove, pushed out from the ventral wall of that part of the digestive cavity which may be called the pharynx, though at this time there are no gill openings connecting this cavity with the exterior.

This groove, or beginning thyroid, was first found, in ~~the~~ P. planeri ~~material~~, in an embryo eleven days old, that is to say, eleven days after fertilization.

The external appearance of this embryo is seen in Fig. 1 a. At this stage there is no external indication of gill-slits, the mouth is deeply pitted in, though not yet broken through, and the yolk still forms a large, round mass at the posterior end of the embryo. As is seen by the figure, the embryo is distinctly retort-shaped, the yolk-mass forming the body of the retort, while the neck of the retort is represented by the head and neck regions of the embryo. The stomodæum is seen as a pit in the head region, and, at a slightly older stage, the first external indication of gill-clefts is seen as a series of shallow transverse grooves in the narrowest part of the neck of the flask.

The thyroid groove, at its anterior end, is broad and deep, so that, with its thick walls, it is half as large, in cross section, as the part of the pharynx from which it is de-

rived. Its lateral walls are, throughout its length, very thick, and are composed of a single row of greatly elongated cells, each cell with a large nucleus near its centre. The ventral wall is usually much thinner and is composed of shorter, even cubical,cells.

As the groove is followed posteriorly, it is found to become gradually narrower and also somewhat more shallow until it finally disappears.

Fig. 1 c, though representing a slightly older stage, may be taken to represent a transverse section through the middle of the gland very shortly after its first appearance as an evagination from the floor of the pharynx (phar.). The thick lateral walls and much thinner floor of the thyroid are shown in this section. Anterior to the point represented in this figure, the thyroid groove is somewhat wider, while posterior to this point it is slightly narrower and gradually becomes more and more shallow until it finally disappears.

The thyroid at this stage, then, is a groove, relatively larger, perhaps, than at any other time, and opening along its entire length into the pharynx.

(12th day.) On the twelfth day the thyroid begins to be shut off from the pharynx by the growth of two horizontal partitions, one roofing over the anterior end, the other roofong over the posterior end, of the thyroid groove.

These partitions or septa are shown at a slightly later stage in Fig. 3, which is a sagittal section through the anterior end of a thirteen-day embryo, cutting the thyroid almost medially and passing slightly to the side of the medial line of the mouth invagination. The anterior septum (a. h. l.) is seen to be further advanced than the posterior one, which is just beginning (p.h.l.). In this figure the cells of the thyroid evagination are stippled to distinguish them from the remaining cells of the pharyngeal wall. That the section represented in Fig. 3 did not cut the thyroid in an exact median plane is shown by the much elongated cells which form the floor of the groove. The section was probably somewhat oblique. The body wall of the embryo is shown in outline (b.w.), and the first indication of gill clefts is seen as two or three evaginations of the pharynx dorsal and anterior to the thyroid (v.c.). A transverse section of the twelve-day embryo through the anterior end of the thyroid (through the line ab in Fig. 3) shows that it is now a closed cavity (Fig. 1 b), with thick walls, lying just beneath the pharynx and between two large blood vessels. Throughout the mesoblast that surrounds the thyroid are scattered numerous yolk granules, the mesoblast cells themselves being rounded and very different in shape from what they will be in later stages. The cells in the floor of the pharynx are not so sharply differentiated from those in the roof of the thyroid as is

indicated in this figure. The cells of the body wall are very similar in size and shape to those lining this part of the pharynx. Fig. 1 c. is a section cut posterior to Fig. 1 b., (through the line a'b'. in Fig. 3) and passes through the part of the thyroid which is still open above to the pharynx. In Fig. 1 b. only the cells of the thyroid are dotted, while in Fig. 1 c. the cells of both thyroid and pharynx are dotted. The only change since the eleven-day stage is the beginning of the horizontal septa, the anterior end of the thyroid being converted into a closed tube by the backward growth of the anterior septum.

The septa seem to be formed by a rapid growth at the points where the most anterior and the most posterior epithelial cells of the thyroid merge into those of the pharynx, causing these two projections to be pushed out, the upper layer of each septum apparently being derived from the pharyngeal epithelium, the lower from what may be called the epithelium of the thyroid (Fig. 3). The thyroid, though closed in anteriorly, is still entirely open above for a greater part of its length. As is seen in Fig. 1 b., the dorsal wall of the thyroid is closely pressed against the ventral wall of the pharynx, so that it is difficult to distinguish the two walls.

It will be interesting to compare the of Petromyzon thyroid at this stage with the thyroid, at a corresponding stage, in Amblystoma (Figs. 8 a and 8 b). A section through the

anterior end of the of Petromyzon thyroid (Fig. 1 b.) shows it to be a closed cavity while posteriorly it is still an open groove (Fig. 1 c.). In Amblystoma, on the other hand, the open groove is anterior to the closed part of the gland, the closing in taking place apparently in a postero-anterior direction.

(13th and 14th days.) At about this time the lateral walls of the thyroid, especially towards the anterior end, become greatly thickened by the increase in length of the columnar cells of which they are composed. At the same time an invagination of these thickened walls occurs as a longitudinal groove pushing inward and upward from the outside of the gland (Fig.2b,i.v.). This invagination becomes still more marked in later stages and extends farther in a posterior direction.

At this stage the extreme anterior end of the thyroid is forked, so that a section through this region would show two distinct cavities with thickened lateral and ventral walls (Fig. 2 a). This is plainly seen in sections and in a wax reconstruction of the thyroid made from a series of sections of this stage. These two divisions of the anterior end of the gland are separated by a vertical partition of mesoblast. The two parts of the thyroid are more widely separated by the mesoblast than they will be at later stages, but at this stage the separation extends only a short distance from the anterior end of the gland. The thyroid is here not so closely pressed against

the pharynx as was the case in previous sections, being separated from the wall of the pharynx by a collection of mesoblast cells. The cavity of each half of the gland is crescentic in cross section, and on the left side is seen the beginning of the lateral invagination.

The thyroid cavity is closed in now for about 2/5 of its entire length, both anteriorly and posteriorly, so that its opening into the pharynx is reduced to a slit extending only 1/5 the length of the gland.

Sections through the thyroid, anterior to this opening (Fig. 2 b.) but posterior to the divided portion of the anterior end, show the cavity to be considerably complicated by the thickening and folding of the walls. The simple, circular cavity of the preceding stage (Fig. 1 b.) is now reduced, by the growth and invagination of the walls, to a narrow vertical slit with lateral diverticula above and below, giving the cavity, in cross section, somewhat the shape of a distorted letter T. The dorsal wall of this cavity (Fig. 2 b, d.l.) is comparatively thin, being composed of a single layer of rather short columnar cells, and is what Dohrn calls the "Decklamelle." The ventral wall is also comparatively thin, and shows in the centre, at the extreme anterior end of the unpaired cavity, a slight upward projection (Fig. 2 b, m.l.) which would seem to be the first indication of the medial longitudinal partition that will later divide the gland into two lateral parts. According to Dohrn, this me-

dial lamella is formed as far back as the opening of the gland, before the lateral invagination takes place, but in my material this is certainly not the case, as is shown in Fig. 2 b.

The lateral invaginations extend posteriorly to a point a little behind the anterior edge of the slit-like opening into the pharynx, Fig 2 c being from a section that cut through the extreme posterior part of the invagination in the right side but was too far posterior to cut that of the left side, either because the section was somewhat oblique or because the right invagination had proceeded further than the left

It is well to get a clear idea of these lateral invaginations in the simple condition represented in Fig 2 b, as the more complicated later stages will thus be more easily understood Were the lateral walls straightened out, thus obliterating the lateral invaginations, the thyroid would be reduced to a more or less cylindrical body, as it was in Fig 1 b, though with a much larger cavity The long cells of the lateral walls are divided by the invagination into two groups, which become more and more distinct as development proceeds In Fig. 2 b one of these groups, on each side, lies between the invagination and the perpendicular part of the cavity of the gland; the other group lies between the invagination and the dorsal, horizontal part of the cavity (Compare Fig 5 e) The cavity of the thyroid between this point and the posterior edge of the opening into the pharynx is simply a deep and narrow groove, slightly

expanded at the bottom where a narrow space is left, on either side, between the thick lateral and thin ventral walls (Fig. 2d). Along this groove-like part of the thyroid the cells of the pharynx and gland pass quite insensibly into one another, and are not sharply distinguishable as might be supposed from the stippling in Figs. 2 c and 2 d. The portion of the thyroid posterior to the opening is a simple tube-like structure, nearly circular in outline and with a vertical slit-like cavity (Fig. 2 e). The walls here are of nearly the same thickness on all sides, and lie in contact with the epithelium of the pharynx above and with that of the body wall below; in fact, throughout almost the entire length of the gland this is the case. On each side of the thyroid throughout its entire length lies a pseudobranchial artery (art.) ("Spritzlocharterie" of Dohrn). There is no indication, as yet, of the ciliated grooves, "Pseudobranchialrinne."

The stages of development which follow were obtained from ~~the~~ Ithaca, ~~material~~, and the larvāe, ~~which material~~, it will be remembered, 2; were ~~was~~ possibly of two species neither of which was identical with the, from Naples material, P. planeri.

The next change that is noticed in the thyroid gland is the development of the median vertical lamella (Fig. 4 a, m.e.) which is formed by the invagination of the thin dorsal and ventral walls, beginning at the anterior end and gradually extending posteriorly until, at this stage, the gland is separated

into two distinct lateral parts, from the anterior end about half way to the opening into the pharynx. Fig. 4 a is a section through the extreme posterior edge of the partition, showing the invagination of dorsal and ventral walls. The once simple tube is complicated now by four invaginations of its walls. The two that have been spoken of as the "lateral invaginations" (i.v.), pushing into the thick side walls in a dorso-median direction, are not very different from ~~what we~~ saw in Fig. 2 b. The other two push towards each other from the roof and floor of the gland (Fig. 4 a, m.l.) until they meet and fuse, thus separating the thyroid into two distinct lateral halves. At a later stage of development mesoblast cells press in between these halves to form a thin mesoblastic partition. At this stage the mesoblast is composed still of closely-packed, rounded cells, and contains a few scattered yolk granules. It is at this time also that the first trace of the ciliated grooves (the "Pseudobranchialrinne") makes its appearance as a groove in the floor of the pharynx, extending anteriorly a short distance from the opening of the gland (Fig. 4 b, v.c.g.). At this stage no cilia could be seen, and the groove was much wider than it was at later stages of development. The cavity of the gland, in the region represented in Fig. 4 b, still retains, in cross section, its resemblance to the letter T. This section is anterior to the duct, but posterior to the median lamella represented in Fig. 4 a. The other changes noticed at this stage are :- the closing of the

slit-like opening into the pharynx until only a small circular canal is left (no section through this opening is represented); the thinning of what we shall hereafter call, after Dohrn, the "cover"cells ("Decklamelle") (Fig. 4 b, d.l.), and the thickening and deeper invagination of the "gland" cells ("Drüsenlamelle") (Fig. 4 b, g.l.). The part of the gland posterior to what we may call now the "duct" remains about as in the preceding stage (Fig. 4 c).

The larvae of the next stage were about nine mm. long, and showed all the outward characteristics of the normal Ammocoetes. An outline drawing, from life, of the side of the head is shown in Fig. 5 a. Being drawn under the microscope with a camera, the relative size and position of the thyroid are accurately shown. The gland is seen to extend from the first to the fifth gill arch, and to be closely wedged in between the pharynx above and the body wall below. The upwardly curved ends did not show in the living animal, except as indicated by the upward bending of the longitudinal grooves; neither did the duct leading to the pharynx, so these features were omitted in this illustration. The longitudinal grooves are exaggerated somewhat in the drawing. The gland, in life, had a faintly yellow color, while the rest of the larvae, except the blood, was nearly white, with numerous many-branched, black pigment spots resembling very complicated nerve cells. The living larva of this age is quite transparent, so that the pulsation of the heart and of the velum

(v.), and the circulation of the blood through the branchial arches can be seen easily under a low power. The thyroid, being rather more opaque than the rest of the animal, shows very plainly by contrast. In the figure the outlines of the pharynx and the positions of the arches are shown by the broad dotted lines. The characteristic hood-like projection over the mouth is also shown. With the exception of the eye (e.), no attempt has been made to represent any of the other organs of the larva.

A ventral view of the larva of this age shows the thyroid as a clearly defined elongated body, lying against the ventral wall of the pharynx.

By this time great advances have been made in the development of the thyroid and of the ciliated grooves. Fig. 5 b is a transverse section a short distance anterior to the thyroid. It shows the spinal cord (sp.c.), notochord (ch.), body wall (b.w.), etc. in outline, while the cell structure of the pharynx (phar.) is shown. This section, on the right side, passes through the ciliated groove at the point (1) where its anteriorly-directed, ventral branch (v.c.g., on the left) turns dorsalward to run posteriorly as the dorsal groove (d.c.g., on the left). On the left of the section the two branches of the groove are distinct as a dorsal (d.c.g.) and ventral (v.c.g.) groove. These grooves are lined with cells which are much higher and more columnar than the cells of the rest of the pharyngeal wall, so that they are easily followed, by sections, throughout their course.

Their cilia are short and indistinct.

The mesoblast (mes.) surrounding the thyroid and pharynx is now quite different from that of earlier stages, being composed of scattered angular cells instead of closely packed, more or less oval cells. The yolk has disappeared. The outline of the pharynx is represented in a somewhat diagrammatic manner, though it was traced as accurately as possible under a camera.

Fig. 5 c shows the wide separation of the dorsal and ventral branches of the ciliated grooves so that the two dorsal branches are now quite near together at the mid-dorsal line (d.c.g.), while the two ventral branches also are seen to approach each other as they pass posteriorly along the walls of the pharynx. (v.c.g.). The dorsal grooves continue to approach each other gradually as they are followed posteriorly until they are separated only by a median ridge of ciliated columnar cells (Fig. 5 d). At a point a short distance anterior to the thyroid the grooves disappear and the medial ridge continues posteriorly, though diminished in height, as the <u>ciliated</u> dorsal ridge (Fig. 5 k, c.d.r.). This ridge continues to the extreme posterior end of the pharynx and enters the oesophagus, of which it forms, for some distance, the ciliated dorsal wall.

The ventral grooves, as has been said, approach the mid-ventral line of the pharyngeal wall until they unite and lead into the duct of the gland (Figs.5e-i). Posterior to the

opening into the thyroid they are continued on the floor of the pharynx as a single, shallow, median groove (Figs. 5 j-k), which finally disappears posterior to the thyroid as a groove, but continues to the oesophagus as a ridge of thickened epithelium. In an embryo cut sagitally so that the pharynx may be laid open and exposed from above, the ciliated grooves may be seen easily with the naked eye, and still more plainly with a lens, but no indication of grooves or bands running from the dorsal ciliated ridge to the ventral groove is to be made out. A transverse section through one of the gill arches showed the presence of very fine, short cilia, but their arrangement could not be made out. This arrangement of ciliated grooves is quite different from that described by Willey in his interesting book "Amphioxus and the Ancestry of the Vertebrates." On page 168 he says:-"These grooves curve forwards and upwards in front of the gill clefts (after the obliteration of the first gill-pouches), and then proceed backwards on either side of the dorsal middle line of the pharynx as far as the commencement of the oesophagus. Here they appear to curve downwards again, and uniting together, extend forwards as a median ventral groove to the posterior lip of the hypobranchial aperture."

The arrangement of the ciliated bands and grooves then is briefly as follows:- On the floor of the pharynx, beginning at or near the opening of the oesophagus, is a ridge of epithelium on which no cilia could be made out. This ridge,

after extending forwards for a very short distance, becomes changed gradually into a shallow, median, ciliated groove that continues without change to the duct of the thyroid. Just anterior to the duct the ventral ciliated groove splits into two grooves, which separate gradually, on the floor of the pharynx, and, near the extreme anterior end, pass upward on each side to the roof of the pharyngeal cavity. The grooves then converge as they pass backwards until, at a point anterior to the front end of the thyroid, they unite again and from the median, ciliated, dorsal ridge which extends backwards to the oespohagus, of which it forms, for a short distance, the dorsal wall.

In the gland itself the changes begun in previous stages have been carried now much further. The cover cells (Figs. 5 e-m, d.l.) (Decklamelle) have shortened until they now form a sort of membrane, while the gland cells (Figs. 5 f-m, g.l.) have greatly elongated and their nuclei now lie near one end. The gland is completely divided by the median lamella (Figs. 5 e-h, m.l.) from the anterior end as far back as the duct. From the duct to the posterior end (Figs. 5 i-k, m.l.) the lamella is simply a partition rising from the floor of the gland but not reaching to the roof, its upper edge being swollen for a considerable distance posterior to the duct (Figs. 5 i-k, m.l.). The lateral invagination is very deep and important in determining the structure of the organ. Near the anterior end (Fig. 5 e, i.v.) it has not changed greatly from the condition

in which it was at the last stage, but as we pass to sections farther back we find that the invagination forms a considerable cavity in each lateral half of the gland (Figs. 5 f-h, i.v.), and posterior to the duct the gland, in cross section, is seen to be divided into three distinct parts, a central and two lateral divisions (Figs. 5 i-k). In the posterior part of the invagination mesoblast cells are seen often (Fig. 5 i, mes.).

The most extensive and complicated changes that have taken place are those of the gland cells (g.l.). The first among the changes to be mentioned is the separation of these cells into two groups, the ciliated cells, and gland cells proper. The method of this separation is partly shown in Fig. 5 e. As seen in this section, the nuclei of the gland cells appear to have arranged themselves near the periphery of a somewhat oval mass of cells and to have been pushed in, at one point, by the lateral invagination (i.v.). On the medial side of this oval mass of cells, lying parallel to the median lamella (m.l.), is seen a double row of nuclei, the lateral row (n.gl.) apparently having been separated from the medial row (n.f.l.). The nuclei in the medial row become the nuclei of short columnar cells (Fig. 5 f, f.l.), while the lateral nuclei remain in the gland cells proper (Fig. 5 f,g.l.). A considerable space is formed between the ciliated cells and the gland cells, which becomes connected with the lateral invagination (Figs. 5 f-h, i.v.) by the separation, in the centre (at the end of the line n.g.l., Fig.5e)

of the nuclei of the lateral row (n.gl.) and the joining of these separated ends with the nuclei of the adjacent sides of the invaginated, double row of nuclei; the cells above (dorsal to) the line n.g.l. (Fig. 5 e) joining with those above the invagination (i.v.), and the cells below (ventral to) n.g l. joining the cells on the lower side of the invagination. In other words, the space formed between the ciliated cells and the gland cells becomes connected with the exterior by the breaking through (between the short parallel lines at the end of the reference line n.gl., Fig. 5 e) of the lateral invagination. The nuclei that are connected by the short black lines, referred to above, will lie hereafter in adjacent gland cells.

The result of these changes is not only the formation of a distinct layer of columnar ciliated cells (Fig. 5 f, f.l.), but also the formation of four <u>groups</u> of gland cells in each half of the thyroid. Of these four groups of cells, two are large and have reached nearly their full differentiation at this stage (Figs. 5 e-j, g.r.); the other two (Figs. 5 e-j, g.r'.) are still very small and undeveloped, though even when fully developed they remain somewhat smaller than the first formed groups. The large groups of gland cells are somewhat fan-shaped, when seen in cross section, and are composed of greatly elongated conical cells, whose nuclei lie at their bases.

On account of the great difficulty in obtaining good preparations of these gland cells, as before mentioned, many series

of sections had to be studied before any conclusion could be reached as to the minute structure of the cell groups. The pointed ends of the cells are directed towards the opening (o.) of the cell group, and, in the later stages at least, are usually obscured by the mass of secretion which fills any space there may be in the centre of the cell group. In practically every instance there was a small protuberance at the opening of the cell group (Fig. 5 g and Fig. 6 1, p.s.) which appeared to be a small mass of secretion which had been forced out of the cell group by the contraction of the gland at fixation. There was no secretion found in any other part of the gland, which fact could be explained only by supposing that the secretion was carried away, as fast as it was formed, by the cilia. As seen in Fig.6 1 (a camera drawing of a section of the next stage, magnified 925 diameters), the opening of the cell group is covered over by a membrane which is continuous with the membrane from which the cilia arise. As this membrane, in any given group, may be followed without a break through a long series of sections, and the protuberance of secreted matter seen in each section, it is difficult to see how the secretion gets on the outer side of the membrane, unless it passes through a series of holes in the membrane that, when filled as they are with secretion, are too minute to be seen, even under a magnification of 1200 diameters.

In Fig. 6 1 may be seen, just under the basement mem-

brane, a number of triangular condensations of the cell substance on each side of the opening. These inverted cones were seen in a number of sections that happened to be stained in just the proper way, but no explanation for their presence suggested itself.

Roughly speaking, each half of the thyroid may be considered to be made up essentially of two large and two small cylinders of gland cells, each cylinder extending the whole length of the gland (Fig. 5 e, gr. and gr'.). The small cylinders (gr'.) are as yet so rudimentary that they can scarcely be recognised as such, but, as has been said, they will acquire later the same structure as is now possessed by the larger cylinders (gr.). Extending the entire length of each cylinder or cell group is a narrow band of minute holes, mentioned above (Fig. 5 f, o. and Fig. 6 l, m.), through which the secretion of the gland cells escapes into the ciliated chambers and thence, through the duct, to the ciliated grooves of the pharynx.

The remaining structural details of the gland may be understood from a description of the duct, which is somewhat complicated. As has been described above, the two ventral branches of the ciliated grooves run along the floor of the pharynx, getting closer and closer together until they unite and form a single deep groove (Figs. 5 e-h, v.c.g.). In Fig. 5 f the ventral ciliated grooves (v.c.g.) have almost united, being separated only by a wedge-shaped portion of the pharyngeal floor.

they are deep and so narrow that there would seem to be but little room for ciliary action. The cells lining the grooves are here somewhat shorter than the other cells of the pharynx, whereas more anterior sections showed the reverse to be the case, as was mentioned above (Figs. 5 b-d).

The single ciliated chamber (considering one side only of the bilaterally symmetrical gland) forms about three fourths of a circle (m.c.h.) and is bounded by the *cover* cells (d.l.) on the one hand and by the *ciliated* cells (f.l.) on the other. The *cover* cells have become so much flattened that they from a mere membrane, and their nuclei are pressed far apart. The *ciliated* cells are of a typical ciliated columnar form, and are exposed, at their ciliated ends, to the cavity that has been described as the *ciliated chamber*, and at their basal ends to the space that is now a part of the lateral invagination (i.v.). Several large blood vessels are seen, surrounded by the angular mesoblast cells, and on each side of the thyroid, lying close to the body wall, is a large longitudinal muscle. Before reaching the point at which it opens into the thyroid, the groove spreads out at the bottom (Fig. 5 g, p.) and resembles, in cross section, an inverted letter T. The cross arms of the T turn upward as they pass farther backwards (Fig. 5 h, p.) until they are closely pressed against the vertical part of the T. The way in which this curious groove opens, finally, into the thyroid is interesting. A short distance back of the point represented

in Fig. 5 h, the cells of the ciliated and cover layers are interrupted at about the point marked b.r. (Fig. 5 h) and at the same time the side pouch (p.) of the groove (v.c.g.) becomes separated from the groove itself along the line x-y (Fig. 5 h). By the union, now, of the medial end (1) of the ciliated layer with the end (1') of the adjacent side of the groove, and at the same time by the union of ends 2 with 2' and 3 with 3', we have a condition represented in Fig. 5 i. The end (4) of the cover layer unites with its fellow of the opposite side of the gland to form the swollen upper edge of the partition (m.l., Fig. 5 i) mentioned above. By a careful comparison of Figs. 5 h and 5 i, the relationships just described will become clear.

In Fig. 5 i, then, we have represented a section passing directly through the duct of the gland, and we see that the secretion from the two groups of gland cells (g.r.) passes out of the gland in two ways; that from the ventro-median group passes into the central ciliated chamber (m.c.h.) and thence directly out through the duct (v.c.g.), while the secretion from the dorso-lateral group has to pass into the duct through the side pouch (p.). Anterior to the duct, the ciliated chambers (m.c.h. and l.c.h.) being one, (Fig. 5 f, m.c.h.), the secretion from the different groups of cells may of course pass out either way. The duct is inclined somewhat in a posterio-ventral direction and is lined with ciliated columnar cells. The point at the end of the line 1 (Fig. 5 i) indicates the place of union of

of the medial part (Fig. 5 h, 1) of the ciliated layer with the adjacent side (1') of the deep, ciliated groove (v.c.g.). Reference line 2 shows where the lateral part (2) of the cover layer joined the outer side (2') of the ciliated pouch (p.). Reference line 3 indicates the point at which the lateral part (3) of the ciliated layer joined the medial side (3') of the ciliated pouch (p.). m.l. is the median lamella formed by the union of the medial portions of the cover layers (d.l.) of the two parts of the gland; from this point it is an incomplete partition all the way to the posterior end of the gland.

Posterior to the duct (Fig. 5 j), the medial portion (1) of the ciliated layer joins its fellow of the opposite side, above the median lamella (m.l.), while the outer part (3) of this layer remains continuous with the outer part of the cover layer. By this arrangement the lateral invagination (i.v.) apparently completely separates a lateral from the central part of the gland, as has been mentioned before, and the mesoblast cells are found between the two divisions (mes.). This is shown also in Fig. 5 m, which is a horizontal section of the entire gland. A section at this plane gives the impression that the lateral invagination (i.v.) almost completely separates the lateral from the central portion of the gland, but of course if the section were cut nearer to the dorsal surface of the gland, the lateral portion would be seen to be joined to the central portion anterior to the duct (to the left of m.l.), as has been seen in

Figs. 5 e-h. Fig. 5 m shows the extent to which the gland is completely divided by the partition (m.l.), and also the position of the gland in relation to the gill arches (v.a., 2-5). The cilia are omitted from this figure. In all the sections posterior to the duct, as seen in Fig. 5 j, there are three distinct ciliated chambers. The median ciliated chamber (m.c.h.), occupying the central division of the gland, is triangular in cross section, and is partially divided into two chambers by the median lamella (m.l.) which rises from the middle of its ventral wall. Into each half of the median ciliated chamber empty one of the large and one of the small groups or cylinders of gland cells. The smaller cell group, as has been said, at this stage is still in a rudimentary condition.

The lateral ciliated chamber)l.c.h.) is crescentic in cross section, the lesses curve of the crescent being formed by the ciliated cells, the greater curve by the cover cells. Into the lateral chamber empty a large and a small group of gland cells. Dorsal to the gland are the two large blood vessels (art.) and close above these the floor of the pharynx, with the ventral ciliated groove (v.c.g.), now much diminished in depth. Fig. 5 k is of a section near the posterior end of the gland, passing through the upcurved portion. The reference line m.c.h. begins in the cavity of this upwardly bent part, which is cut through at the point where it is continuous with the central ciliated chamber of the gland. A section just anterior to this

would show this upper space as a separate cavity. Dohrn says this marked bend at the posterior end, as well as the less marked one at the anterior end, is caused by the growth of the gland being more rapid than that of the space in which it is enclosed.

The lateral portions of the gland at the point represented in Fig. 5 k are very small. The central partition (m.l.) is still present, as seen in Fig. 5 l, and imperfectly at m.l'. in Fig. 5 m. The ventral groove (v.c.g.) and dorsal ridge (c.d.r.) are also very plainly seen in Fig. 5 k. The blood vessels are followed easily and are usually filled with large, nucleated corpuscles. In the last two sections (Figs. 5 k and 5 l), the thyroid has diminished in size, and the arrangement of the gland cells into the four groups can be recognized no longer. The lateral ciliated chamber is reduced to a nearly circular cavity, and the ventral ciliated groove is flattening out gradually, preparatory to changing to the low ridge mentioned in the description of the system of ciliated grooves. The ciliated dorsal ridge is very prominent and partially embraces the aorta in its folds. The cell structure of the body wall and of most of the pharyngeal wall is omitted in these as in most of the preceding figures.

In the following and last stage of development (Figs. 6 a-k), the gland has apparently reached its greatest complexity,

as the only noticeable change from the preceding and much younger stage, except increase in size, is the remarkable coiling of the posterior end of the gland, caused, Dohrn says, as has been previously mentioned, by the longitudinal growth of the gland being more rapid than the space in which it is enclosed. The larva from which this stage was taken had reached a length of about 15 cm., and a circumference of about 2.5 cm. in the region of the thyroid.

Fig. 6 j is a ventral view of the anterior end of a larva of this stage, the ventral integument (b.w.) of which has been dissected along the mid-ventral line and drawn to each side, so as to expose the thyroid gland (thy.). The figure shows the shape of the gland as seen from the ventral side, and also its relative size and position. The cartilaginous bars (c.b.) of the branchial basket are also shown, and it is seen that the large mid-ventral bar divides, when it reaches the posterior end of the gland, into two lateral bars, one of which lies close to each side of the thyroid throughout nearly the entire length of the gland. The longitudinal grooves (ventral and lateral invaginations) are quite indistinct because of the mass of white, fibrous-looking connective tissue which now surrounds the gland on all sides. At this stage, as is seen in Fig. 6 j, the gland extends from the middle of the first to the middle of the fourth gill pouch (g.p.) and is about 1/3 the diameter of the entire pharynx.

In a ventral view, the coil of the posterior end of the gland does not, of course, show, but at each end is seen a median groove which shows, even through the fibrous envelope; these grooves are caused by the separation of the two parts of the gland, at each extremity, whereas throughout most of their length the halves are in close contact with each other. The numerous transverse folds in the seven pairs of gill pouches are seen in this figure, and also the fibrous character of the anterior wall of the pharynx. The actual oral opening is not shown.

Fig. 6 k is a diagrammatic side view of the gland, to show the points through which the sections were cut, and also to show longitudinal space relations, such as size and position of duct, extent of coil, etc. Being carefully reconstructed and drawn by scale, it shows these relations with more or less accuracy. As is seen from this diagram, the duct lies a little nearer the posterior than the anterior end of the gland, though if the coiled posterior end of the gland were straightened out, the duct would then be considerably nearer the anterior end. By comparing Fig. 6 c with this diagram, it will be noticed that the duct is now a longitudinal slit instead of a nearly circular duct, the lateral growth of the duct apparently not having kept pace with the longitudinal. Fig. 6 k represents the actual relative <u>longitudinal</u> but not <u>vertical</u> dimensions of the duct. The actual increase in size of the gland may be appreciated by noting that, though all the sections were drawn with a camera,

those represented in Figs. 5 b-l are enlarged 240 diameters, while those in Figs. 6 a-i are magnified only 90 times.

A section through the anterior end of the gland, passing through the point marked a, Fig. 6 k, is represented in Fig. 6 a. The chief difference, besides that of size, between this section and the corresponding one of the preceding stage (Fig. 5 f), is in the complete development of the cell-groups (gr'.), which in the preceding stage were quite small and undeveloped. We have now in each side of the gland, which is exactly bilaterally symmetrical, four groups of gland cells, the groups being arranged in pairs, one pair on each side lying near the middle line, the other being nearer the side (Figs. 6 e and k, m.c.g. and l.c.g.). This arrangement of the cell-groups into pairs is distinct from end to end of the gland, and for convenience they will be spoken of as the "median" and "lateral" pairs of cell-groups. As has been said, the groups gr'. never reach the size of the first developed groups gr.

The ciliated cells have changed somewhat since the preceding stage. They have become relatively, as well as actually, more elongated at certain parts of the ciliated layer, while at other places they are still short and nearly filled with their large oval nuclei. The nuclei of the longer cells are small and circular in outline, and at certain places seem to be more or less regularly arranged near one end or other of

the cells, while at other places there is no apparent regularity in their arrangement. In Fig. 6 a, the short cells with large nuclei are seen on either side of the slit-like openings (o.) into the groups of gland cells. The ciliated grooves (v.c.g.), at the point where this section is cut, are still some distance apart on the floor of the pharynx, and are not noticeably changed from their condition in the preceding stage. They are separated by one large and two small folds in the floor of the pharynx, which seems, at this point, to be very irregular in outline, probably caused partly by shrinkage at fixation. They are very deep and narrow and seem filled completely by their cilia.

The connective tissue covering (c.t.) of the thyroid, spoken of in connection with the outward appearance of the thyroid, is seen, in section, to form a thick layer entirely around the gland, and to form the central mass of the median lamella (m.l.). It also forms a thick coating around each branch of the large artery which Dohrn calls the Pseudobranchial artery (Spritzlocharterie) (art.). The large, and now nearly enclosed space (i.v.), formed by what was called the "lateral invagination", is more or less completely filled by a sort of reticulated tissue with scattered nuclei. This reticulated tissue also fills the space between the floor of the pharynx and the thyroid. Numerous small blood vessels are found imbedded in it, both in that which fills the lateral invagination and in that which lies between the gland and the pharynx. This tissue is represented only in

Figs. 6 a and 6 b, but the fibrous tissue is shown in all the figures of this stage.

Fig. 6 b represents a section cut a short distance anterior to the duct, at the point b Fig. 6 k, and about corresponds to Fig. 5 h of the preceding stage. The ciliated grooves at this point have united to form a single deep groove which is spread out at the bottom to form the side pockets (p.) described in the preceding stage. The lateral and median pairs of cell-groups have approached each other until their adjacent groups are nearly or quite in contact; at the same time the ciliated layer (f.l.) has increased somewhat in length, and, at its dorso-median angle(at the end of the lines f.l., Fig. 6 b), its cells have changed from the tall columnar with small, round nuclei to short cells, almost completely filled with their large oval nuclei and resembling the cells that lie close to the openings (c.) of the groups of the gland cells. It is this group of cells, lying in the dorso-median portion of the ciliated layer, that separates into two about equal parts, a little farther posteriorly, to connect the gland with the deep ciliated groove in the manner described in the preceding stage and shown in Figs. 5 h-i of that stage and in Fig. 6 c of the stage now under discussion. The ciliated layer is somewhta folded, as though it had increased in length very rapidly, or had been compressed by the shrinkage of the connective tissue (c.t.) surrounding the gland. There is considerable space at this point between the pharynx and the

thyroid which necessitates the very deep ciliated groove shown in this and the next figure. The arteries (art.) are very large and are bound closely to the gland by the connective tissue mentioned above. The cover layer (d.l.) in these sections is reduced to such a thin membrane that it is often difficult to distinguish it from the connective tissue to which it is closely applied throughout.

A section passing directly through the opening of the duct into the gland is represented in Fig. 6 c. The duct, a deep, narrow slit, is lined with short, ciliated columnar cells, similar to the shorter cells of the ciliated layer spoken of above. These short cells lead quite suddenly into the long cells of the ciliated layer (f.l.).

The lateral pair of cell-groups (l.c.g.) is now entirely distinct from the median pair (m.c.g.), and the pocket (p.) by which the lateral cell-groups are connected with the duct, as before explained, is continued to the extreme posterior end of the gland, the two lateral pairs of cell-groups taking no part in the posterior coil but continuing back of this for some distance (Figs. 6 i and k).

The median lamella (m.l.), which back to this point has completely divided the gland into two parts, is, from this point, merely a tall ridge (Fig. 6 c, m.l.) projecting upwards into the median ciliated chamber (m.c.h.) and covered by the cover cells (d.l.) (Decklamelle) of the two median pairs of cell-

groups. As in the preceding stage, the dorsal edge of this ridge is at times somewhat thickened.

The space between the anterior end of the coil and the duct is short, as is seen by Fig. 6 k, and a section through the gland in this region (Fig. 6 d) differs very little from a corresponding section on the preceding stage (Fig. 5 j) except in the particulars already pointed out for the anterior end of the gland. The median ciliated chamber (m.c.h.) is long and narrow in a dorso-ventral direction and its dorsal part is made up of the shorter form of ciliated cells. The lateral ciliated chamber (l.c.h.) is also much more extensive than in the preceding stage. The ciliated groove (v.c.g.) is seen above the gland in the floor of the pharynx. It is much less deep than it was just anterior to the duct, and remains in about this condition to a point beyond the extreme posterior end of the gland. There is still a considerable space between the thyroid and the floor of the pharynx, which space is filled with the reticulated tissue mentioned above and shown in Figs. 6 a and 6 b.

The following four sections (Figs. 6 e-h) all pass through the coiled posterior end of the gland, at the points indicated by the corresponding letters in Fig. 6 k. The apparent complexity of these four sections will be made plain by comparing them with the diagrammatic lateral view of the gland (Fig. 6 k). In all four sections, what we have called the lateral pairs of cell-groups (l.c.g.) remain the same and may be

recognized by their long, curved, lateral ciliated chambers (l.c.h.).

In Fig. 6 e the median pairs of cell-groups are seen in a mid-ventral position (m.c.g.) as they are followed in an anterior-posterior direction, again in a mid-dorsal position (m.c.g'.) as they are followed in a posterior-anterior direction, and again in nearly the centre of the gland at m.c.g''. as they are followed toawrds the posterior end again. This is easily understood by noting the position of the line e in Fig. 6 k, which shows that the section is cut at the point where the posterior-anteriorly directed part of the median cell-groups (m.c.g'.) turns ventralward to pass again towards the posterior (m.c.g''.). The central ciliated chamber (m.c.h.) is thus seen, is this section, to be continuous from the dorsal (m.c.g'.) to the middle (m.c.g''.) position of the median cell-groups. The general character of the various groups and layers of cells remains about the same in all four of these sections, so that is will be only necessary to speak of their position and arrangement in the sections.

The next section (Fig. 6 f) cuts the median cell-groups in four places, as is shown in Fig. 6 k, at m.c.g. in the anterior-posteriorly directed portion, at m.c.g'. in the dorsal, posterior-anterior portion, at m.c.g''. in the part that is directed again towards the posterior end, and at m.c.g'''. in the last whorl of the coil which is directed towards the anterior

end of the gland. It will be noticed in this and in the other sections passing through the coiled part of the gland, that the median lamella (m.l.) extends into the coil only a short distance. It extends through the dorsally directed part of the coil shown in Fig. 6 h, and for a short distance in the posterior-anteriorly part lettered m.c.g'. Whether it was never found in this end of the gland, or whether it was flattened out by compression was not determined. The shape of the median ciliated chamber varies considerably in the different whorls of the coil, as is seen in Fig. 6 f, m.c.h. In its ventral position, that is, in the position lettered m.c.g., the ciliated chamber has the same outline as in previous sections, and is divided by the median lamella (m.l.). In its dorsal position (m.c.g'.) it is a large chamber undivided by a median lamella. In the middle of the coil, especially in the position lettered m.c.g'''., the chamber is much diminished, apparently by the pressure of the surrounding whorls of the coil. By remembering that the groups m.c.g'. and m.c.g'''. are inverted, as a comparison with the line f in Fig. 6 k will show, it will be seen that the gland is, in reality, no more complicated than it was further forward. Nothing further need be said of this section.

Fig. 6 g represents a section cut through the point where the posteriorly directed whorl (m.c.g''.) turns dorsalward to pass anteriorly as the innermost whorl (m.c.g'''.) of the coil.

Fig. 6 h shows the most posterior of the four sections passing through the coil. It passes through the point where the median cell-groups (m.c.g.) make their first bend dorsalward to where they turn again to form the anteriorly directed whorl (m.c.g'.).

As has been previously said, the lateral cell-groups (l.c.g.) take no part in the posterior coil but extend for a considerable distance posterior to the coil, somewhat diminished in size, and gradually approach each other until they are in close contact.

Fig. 6 i represents a section taken at a point about midway between the extreme posterior end of the gland and the posterior surface of the coil. It shows the two pairs of lateral cell-groups (l.c.g), each with its characteristically curved lateral ciliated chamber (l.c.h.). Just posterior to the coil the two large pseudobranchial arteries, which were seen on each side of the gland in all the preceding sections (Figs. 6 a-h, art.), unite to form the one large artery seen in Fig. 6 i,art. lying between the gland below and the ciliated groove above. This artery is very large, being almost as great in cross section as the end of the thyroid below it. The wall of the pharynx is separated from the gland by a comparatively small space, so that it is evidently pushed upward by the large coiled end of the gland and sinks down again just behind this elevation. The groups of gland cells have diminished somewhat in cross section, but they

are not greatly diminished even at their extreme posterior end.

If, as Dohrn says, the coiling of the posterior end of the thyroid gland is caused by its longitudinal growth being more rapid than the space in which it lies, it is difficult to see why the lateral cell-groups have not taken part in the coil, instead of projecting as they do for a considerable distance posterior to the coil.

The Thyroid and Salivary Glands in the Adult Lamprey.

The condition of the thyroid in the adult lamprey was studied in several large sea lampreys (P. marinus) taken at the herring fisheries of the Susquehanna River, and in a couple of brook lampreys (P. branchialis) from Ithaca, N. Y.

Wilhelm Müller says (Jenaische Zeitschrift, Bd. VII) that the thyroid, in the"sexually mature" animal, extends underneath the long tongue muscle from the 2nd to the 4th gill sac, and is built up of a number of closed follicles lined with intensely brown-yellow epithelium. He says it cannot be mistaken for the salivary gland, lying under the eye and opening by a duct into the mouth.

A study of serial sections of a couple of recently transformed brook lampreys confirmed Müller's description of the position and anatomy of the adult thyroid, but careful dissection of one or two adult sea lampreys and even sections of part of the floor of the pharynx failed to show any trace of the thyroid. As the brook lampreys were, as has been said, only just transformed, while the sea lampreys were killed at sexual maturity, it is possible that the thyroid, which is ductless and a mere rudiment in any case, had nearly or quite disappeared in the older animals. As is seen in Fig. 10 a, the thyroid, which in the younger larval stages was enormously large, proportionally,

is a small group of follicles lined with columnar or cuboidal epithelium (Fig. 10 b). It is surrounded by connective tissue and lies between the tongue muscle above and the median ventral cartilaginous bar below, with a large blood vessel on either side. It extends, as Müller says, from the 2nd to the 4th gill pouch. The follicles are generally filled with a secretion (not shown in the figures) ~~and~~ which, with the their surrounding cells, form~~s~~ in cross section, an oval mass. Usually from four to six follicles are cut in each transverse section.

Born was the first to describe correctly the salivary or basilar gland in the lamprey, Rathke having mistaken the basilar muscle, in which the gland lies imbedded, for the tissue of the gland, considering the true gland as merely the cavity.

The gland is paired, and each half lies, as has just been said, imbedded in the tissue of the corresponding half of the large, paired basilar muscle. This muscle lies in the floor of the mouth and pharynx and is one of the muscles used by the animal in adhering to rocks or fish. By contraction of this muscle the salivary gland is compressed and its secretion thus forced out.

In the large adult sea lamprey the two parts of the basilar gland are easily discovered by dissection, lying in the medial sides of their corresponding halves of the basilar muscle. In the much smaller brook lamprey, the position and structure of the basilar gland may be made out by stained serial sections

(Figs. 9 a and 9 b). Each half of the gland is a thin walled ovoidal sac, about 2cm. long and 8 mm. in cross section, in the sea lamprey. The epithelial cells of the walls are of a short columnar form, and the walls are thrown into numerous irregularly-arranged papillae and short folds, which project into the cavity of the gland (Figs. 9 a and 9 b).

From the medial side of the gland, a short distance back of its extreme anterior end, the duct leads forward, gradually approaching its fellow of the opposite side, but never meeting it, to open into the mouth cavity through a small papilla. Little or no secretion was seen in the gland. The posterior end of the gland is separated from the first gill sac by a distance about equal to the space occupied by two gill sacs.

Figure 9 a represents a transverse section through the ventral part of the body of an adult brook lamprey. The large basilar muscle (b.m.) is seen on each side, between the body wall (b.w.) below and the pharynx (phar.) above. Imbedded in this muscle is the basilar or salivary gland (b.g.) whose walls are thrown into irregular folds and papillae, as has been mentioned.

Figure 9 b is anterior to 9 a and is drawn under greater magnification. One side only of the gland is shown, the section passing through it just anterior to the opening of the duct (d.) into the gland. This figure shows that the folds in the wall of the gland are formed by invaginations, of irregular form and at

irregular intervals. The wall of the duct is of about the same thickness as that of the gland, but is not thrown into folds. The duct diminishes in size somewhat as it passes forwards.

As no trace whatever of this basilar or salivary gland ~~could be found~~ in even the oldest larvae at hand, which must have been very nearly ready to undergo transformation, ~~though~~ [illegible] several well preserved and stained series ~~were examined~~ [illegible], it seemed possible that this gland might have been developed from the anterior part of the larval thyroid, or from the pair of deep ciliated grooves which run forward from the opening of the thyroid and which are not present, as such, in the adult condition.

The similarity in the secretion and function of the larval thyroid to the secretion and function of a salivary gland seems to support this view. The author hopes, with the aid of proper material, to be able to prove definitely whether or not there is any relation between the larval thyroid and the salivary gland of the adult Petromyzon.

Lettering.

a.h.l.	anterior horizontal lamella.
aort.	aorta.
art.	pseudobranchial artery.
b.g.	basilar (salivary) gland.
b.m.	basilar muscle.
br.	point of separation of ciliated and of cover cells.
b.w.	body wall.
c.b.	cartilaginous bars.
c.d.r.	ciliated dorsal ridge.
ch.	notochord.
c.t.	connective tissue envelope.
d.	duct of basilar gland.
d.c.g.	dorsal ciliated groove.
d.l.	cover cells (Decklamelle).
e.	eye.
f.l.	ciliated cells.
g.l.	gland cells (Drüsenlamelle).
g.p.	gill pouch.
gr.	primary group of gland cells.
gr'.	secondary group of gland cells.
i.v.	lateral invagination.
l.	loop of the ciliated groove.
l.c.g.	lateral cell-group.
l.c.h.	lateral ciliated chambers.
m.	membrane over o.
m.c.g., m.c.g'., etc.	median cell-groups.
m.c.h.	median ciliated chamber.
mes.	mesoblast.
m.l.	median lamella.
m.l'.	extreme posterior end of median lamella.
n.fl.	nuclei of ciliated cells.
n.gl.	nuclei of gland cells.
o.	slit-like opening of cell-groups.
oes.	oesophagus.
p.	side pouch of ventral ciliated groove.
phar.	pharynx.
p.h.l.	posterior horizontal lamella.

p.s.	protuberance of secreted matter.
s.	secretion.
sp.c.	spinal cord.
sto.	stomodaeum.
thy.	thyroid gland.
t.m.	tongue muscle.
u.l.	upper lip.
v.	velum.
v.a. 1, 2, etc.	1st, 2nd, etc. visceral arches.
v.c.	visceral clefts.
v.c.g.	ventral ciliated groove.
x-y.	line through which the separation of the side pouch from the ventral ciliated groove takes place.

Explanation of Plates.

All sections drawn with a Zeiss Camera Lucida.

Fig. 1 a. Larva of P. planeri, 11 days after fertilization; to show the external appearance of the larva at the time of the first trace of the thyroid. (Mag. 65 diam.)

Fig. 1 b. Transverse section of 12-day larva of P. planeri, through the anterior end of the thyroid, just anterior to the opening into the pharynx. Shows the gland as a circular cavity, lined with columnar cells, lying under the digestive cavity. (Mag. 325 diam.)

Fig. 1 c. Transverse section posterior to Fig. 1 b through the anterior part of the opening of the thyroid into the pharynx. (Mag. 325 di5m.)

Fig. 2 a. Transverse section through the extreme anterior end of the thyroid of a 14-day P. planeri ~~larva~~. (Mag. 325 diam.)

Fig. 2 b. Transverse section posterior to Fig. 2 a but anterior to the opening of the gland into the pharynx. Shows beginning of lateral invagination. (Mag. 325 diam.)

Fig. 2 c. Transverse section posterior to Fig. 2 b through the anterior part of the opening of the gland into the pharynx. (Mag. 325 diam.)

Fig. 2 d. Transverse section posterior to Fig. 2 c through the posterior part of the opening of the gland into the

pharynx. (Mag. 325 diam.)

Fig. 2 e. Transverse section through the gland, posterior to the opening into the pharynx. (Mag. 325 diam.)

Fig. 3. Sagittal section through the head of a 13-day P. planeri ~~larva~~, passing almost through the median plane of the thyroid and somewhat to one side of the centre of the stomodaeum. Shows the beginning gland as an evagination of the floor of the pharynx. The anterior and posterior horizontal lamellae, which finally separate the gland from the pharynx, are just beginning to be formed. (Mag. 325 diam.)

(Figs. 4-7 are taken from the material obtained at Ithaca, N. Y., and are therefore either of the lake or of the brook lamprey or, perhaps, of both).

Fig. 4 a. Transverse section through the anterior end of the thyroid, passing through the extreme posterior edge of the vertical lamella. Shows beginning of differentiation of cells into "gland" and "cover" cells. (Mag. 240 diam.)

Fig. 4 b. Transverse section posterior to Fig. 4 a, cutting the gland just anterior to the duct, and showing the first trace of the ciliated groove. (Mag. 240 diam.)

Fig. 4 c. Transverse section near the posterior end of the gland, posterior to the duct and to the lateral invaginations. (Mag. 240 diam.)

Fig. 5 a. Lateral view of the head of a 9mm. larva, to show the relative size of the thyroid gland, and its position

in relation to the gill arches, etc. (Drawn from the living animal under a magnification of 50 diam).

Fig. 5 b. Transverse section through the head of a of Petromyzon larva, anterior to the thyroid, through the point where (on the right side) the ciliated groove turns from the dorsal towards the ventral side of the pharynx. The section cuts exactly through the end of the loop on the right side but somewhat posterior to this point on the left side. (Mag. 240 diam.)

Fig. 5 c. Transverse section a short distance posterior to Fig. 5 b, to show how the dorsal branches of the ciliated grooves approach each other, on the roof of the pharynx, as they pass towards the posterior; and the same for the ventral branches on the floor of the pharynx. (Mag. 240 diam.)

Fig. 5 d. Transverse section posterior to Fig. 5 c and just anterior to the gland. Shows the dorsal ciliated grooves separated only by a ridge of cells which a short distance further towards the posterior becomes the ciliated dorsal ridge. The ventral grooves also are seen nearer together. (Mag. 240 diam.)

Fig. 5 e. Transverse section through the anterior end of the thyroid. Shows the still nearer approach of the two ventral grooves. The cover cells are flattened out into a thin membrane, while the gland cells are very long, are splitting off from their nucleated ends the cells to form the ciliated layer and begin to show an arrangement into the four cell-groups.

The lateral invagination deeply indents each of the halves into which the gland is divided by the median lamella. (Mag. 240 diam.)

Fig. 5 f. Transverse section posterior to Fig. 5 e. The ciliated grooves are nearly joined, the ciliated layer of cells is now distinct, as are two of the four cell-groups. The lateral invagination is very deep. (Mag. 240 diam.)

Fig. 5 g. Transverse section posterior to Fig. 5 f but still anterior to the duct. The ciliated grooves have united to form a single deep groove which is here spread out at the bottom, giving it the shape, in cross section, of an inverted letter T. The structure of the gland is now about the same as in the preceding section. (Mag. 240 diam.)

Fig. 5 h. Transverse section posterior to Fig. 5 g and just anterior to the opening of the duct. The structure of the gland is the same as in Fig. 5 g but the shape of the ciliated groove has changed somewhat. (Mag. 240 diam.)

Fig. 5 i. Transverse section through the opening of the duct into the ciliated groove. Shows that the median ciliated chamber opens directly into the deep ciliated groove, while the lateral ciliated chambers open into the ciliated groove through the side pouches noticed in the last two preceding figures. The lateral invaginations, from this point to the posterior end, divide the gland into three distinct parts, a median

and two lateral parts. The median lamella is no longer a complete partition and shows a decided swelling on its dorsal edge. (Mag. 240 diam.)

Fig. 5 j. Transverse section a short distance posterior to the opening of the duct. The ciliated groove is still present but much diminished in depth. (Mag. 240 diam.)

Fig. 5 k. Transverse section posterior to Fig. 5 j passing through the beginning posterior coil. Shows the now broad and shallow ciliated groove close to the top of the gland, and the ciliated dorsal ridge on the roof of the pharynx. (Mag. 240 diam.)

Fig. 5 l. Transverse section through the extreme posterior end of the gland. (Mag. 240 diam.)

Fig. 5 m. A horizontal section through the thyroid, showing the extent of the complete median lamella, the relative position of the visceral arches, etc. (Mag. 240 diam.)

Fig. 6 a. Transverse section through the anterior end of the thyroid of a 10cm. ~~Petromyzon~~ larva. All four groups of cells are now fully developed, and the gland has increased greatly in size, as is shown by the fact that Figs. 5 a-m were magnified 240 diameters, while the larger Figs. 6 a-i were magnified only 90 times. This figure about corresponds to Fig. 5 e of the preceding stage.

Fig. 6 b. Transverse section posterior to Fig. 6 a and just anterior to the opening of the duct. Corresponds to Fig. 5 h of the preceding stage. (Mag. 90 diam.)

Fig. 6 c. Transverse section through the duct of the gland. Corresponds to Fig. 5 i of the preceding stage. The lateral ciliated chambers are much more extensive than in the preceding stage. (Mag. 90 diam.)

Fig. 6 d. Transverse section just posterior to the duct. Corresponds to Fig. 5 j of the preceding stage. (Mag. 90 diam.)

Figs. 6 e-h. Transverse sections through the coiled posterior end of the gland, cut in the planes indicated in Fig. 6 k. (All mag. 90 diam.)

Fig. 6 i. Transverse section through the thyroid, posterior to the coiled posterior end of the gland, to show the manner in which the lateral pairs of cell-groups extend for some distance behind the coiled median cell-groups. The pseudobranchial arteries are seen in this section as a single large vessel. (Mag. 90 diam.)

Fig. 6 j. Ventral view of the head of a 15cm. Petromyzon ~~larva~~, with the ventral integument drawn to one side to expose the thyroid gland. The relation of the gland to the bars of the branchial basket is shown. (Mag. 3 diam.)

Fig. 6 k. Diagrammatic lateral view of the thyroid gland, reconstructed by measurement to show, more or less accurately, the longitudinal relationships of the various parts of the gland. The dotted lines indicate the planes through which the sections (Figs. 6 a-i) pass.

Fig. 6 1. Section through the opening of one of the cell-groups, highly magnified, to show details in structure. (Mag. 925 diam.)

Fig. 7. ~~Petromyzon~~ Larva of a stage between those represented in Figs. 5 and 6. About 2 1/2 cm. in length.

Fig. 8 a. Transverse section through the pharynx and anterior end of the thyroid in Amblystoma, showing the latter as a deep, ciliated groove in the floor of the former. (Mag. 240 diam.)

Fig. 8 b. Transverse section posterior to Fig. 8 a, showing the thyroid as an enclosed tube, lined with cilia. (Mag. 240 diam.)

Fig. 9 a. Transverse section through the ventral half of the head of an adult brook lamprey, to show the position and relative size of the paired salivary or basilar gland. (Mag. about 17 diam.)

Fig. 9 b. Transverse section through one side of the salivary or basilar gland and its duct, just anterior to the opening of the latter into the former. (Mag. 50 diam.)

Fig. 10 a. Transverse section through the ventral half of an adult brook lamprey, cutting through the fourth gill sacs, to show the position and relative size of the thyroid gland. (Mag. 30 diam.)

Fig. 10 b. Transverse section through the thyroid at about the plane of the section represented in Fig. 10 a. (Mag. 420 diam.)

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Note:- While carrying on the present investigation, I brought together all the literature on the subject until I obtained, I think, a nearly complete bibliography of the Cyclostomes. This bibliography will probably appear shortly.

Vita.

The writer, Albert Moore Reese, was born at Lake Roland, Maryland, on the first day of April, 1872. His early education was obtained at the Friends' Elementary and High School, in Baltimore, and he entered Johns Hopkins University in October, 1889, selecting the Chemical-Biological Course.

After receiving the A. B. degree in June, 1892, he taught for five years, during one of which years he was also work~~o~~ing at the above University as a graduate student, with Zoology as a major subject and Palaeontology and Botany as first and second subordinates, respectively. He has continued this line of work during the past three years and was appointed University Scholar for the year 1899-1900.

Baltimore, May 3, 1900.